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Geochemistry and U-Pb zircon dating constraints of some plutonic rocks along Bir Tawilah shear zone, central Saudi Arabia: Implication for magma peterogenesis and age of gold mineralization

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ABSTRACT

The study area covered by this work is located along the Bir Tawilah fault zone which encompasses the Arabian Shield between Afif terrane and western oceanic terranes. The rocks are dominantly ophiolite assemblages, island arc metavolcanic and metasedimentary rocks, and dioritic to granitic intrusions. The diorite and granodiorite rocks are I-type granitoids, calk-alkaline, metaluminous to peraluminous, formed in a volcanic arc setting, whereas the monzogranite is classified as A-type granite, alkaline and highly fractionated calc-alkaline, generated in within-plate tectonic setting. Nb and Y relationships indicated that the diorites and granodiorites were generated by a mafic parental magma contaminated with crustal materials, and controlled by fractional crystallization, whereas the monzogranites were generated from a magma characterized by an enriched mantle (EM) source.

Mineralization including gold is hosted by the carbonatized serpentinite (listvenite) and the syn-tectonic granodiorite along Bir Tawilah thrust zone. U-Pb zircon geochronology indicates that the granodiorite at Jabal Ghadarah is emplaced at ca. 630 ± 12 Ma, probably suggests that the metallic minerals associated with the granodiorite along Bir Tawilah thurst zone are the result of remobilization of pre-existing gold mineralization associated with listevenite that is related to arc accretion.

1. Introduction

Neoproterozoic granitoid rocks are important parts of the Arabian-Nubian Shield (ANS), which extends from Egypt south to Sudan, Eritrea, and Ethiopia on the western flank of the Red Sea and on the eastern flank of the Red Sea from Jordan and Israel south through Saudi Arabia and Yemen. The ANS is a collage of well-preserved tectonostarigraphic terranes (Fig. 1), which are decorated by ophiolitic sutures (Johnson and Woldehaimanot, 2003; Stoeser and Camp, 1985) and represents an excellent example for studying the geologic history and evolution of the juvenile crust during Neoproterozoic time (Kröner, 1985). Terrane formation began at ~870 Ma following the breakup of Rodinia and concluded ~620 Ma when collision between large fragments of East and West Gondwana closed the Mozambique Ocean along the East African-Antarctic Orogen (Stern, 1994; Jacobs and Thomas, 2004). Igneous activity responsible for the formation of ANS metavolcanic sequences is likely to have occurred all through this 250 Ma history (Ali et al., 2009). These island-arc terranes converged and amalgamated as a result of arc–arc or arc-continent collisions and formed large composite terranes (Stern, 1994; Johnson and Woldehaimanot, 2003; Jacobs and Thomas, 2004; Johnson et al., 2011). At the end of this period, the Nabitah orogeny (680–640 Ma) was responsible for the collision and amalgamation of the Arabian Shield terranes (Stoeser and Stacey, 1988; Genna et al., 2002; Johnson et al., 2011). The Nabitah event was associated with a broad zone of deformation, metamorphism and magmatism (Johnson et al., 2011; Robinson et al., 2015). The plutonic arc-related magmatism was extensive during this period and characterized by diorite-tonalite-granodiorite and granite (monzogranite-syenogranite). For example, the Bir Tawilah fault zone which is located along the N-S deformation zone and encompasses the Arabian Shield between Afif terrane and western oceanic terranes, is mainly occupied by a carbonatized serpenti-

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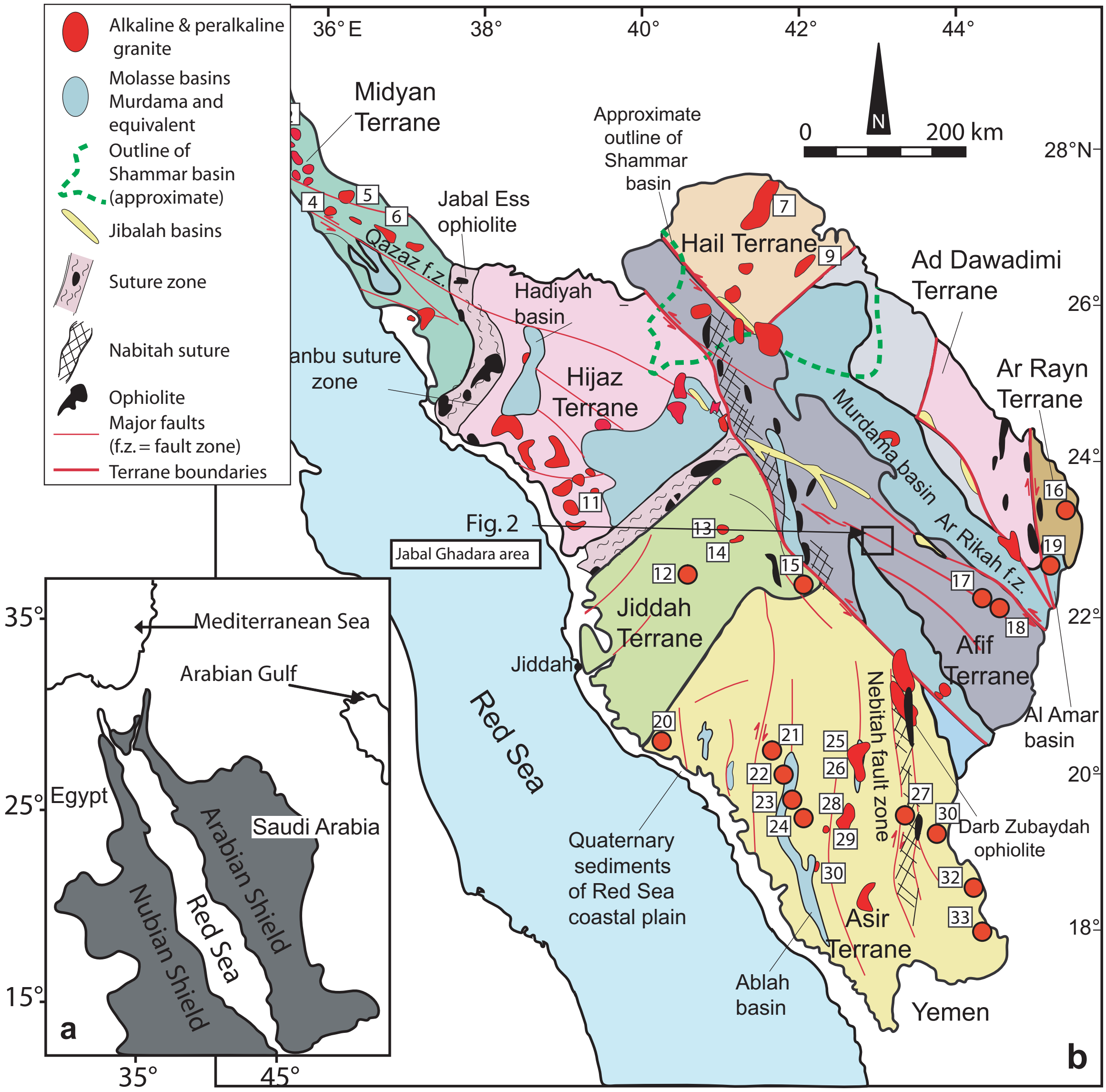

Fig. 1. (a) Simplified map outlining the location on the Arabian-Nubian Shield (ANS). (b) Simplified map of the Arabian Shield, showing major tectonostratigraphic terranes, ophiolite belts, sutures and fault zones, and post-accretionary basins, modified after Nehlig et al. (2002), Johnson and Woldehaimanot (2003), Stern and Johnson (2010). The distribution of the alkaline/peralkaline granites in the Arabian Shield is from Stoeser (1986). Locations of the ring complexes (numbers) are from Roobol and White (1985).

nite (listvenite) and is intruded by granodiorites of Jabal Ghadarah (Fig. 2). Listvenite along Bir Tawilah zone is an important host for gold mineralization. Following the arc orogenic phase, a period of extension and tectonic escape characterized by a huge amount of a post-collisional A-type alkali-feldspar granite and alkaline-peralkaline granite formed in a within-plate tectonic setting (Genna et al., 2002; Greiling et al., 1994; Stern, 1994; Moussa et al., 2008; Be'eri-Shlevin et al., 2009; Johnson et al., 2011; Moufti et al., 2002; Ali et al., 2014). Geochemical studies reveal that the I-type arc-related granitoids are metaluminous to slightly peraluminous, calc-alkaline, subduction-related intrusives (Moussa et al., 2008), developed synchronously with the formation of large molasse basins (Johnson, 1998; Genna et al., 2002; Nehlig et al., 2002; Stern and Johnson, 2010). They show moderate REE enrichment and steep REE patterns with no Eu anomalies. Some of the arc-related granodiorites show high-Al, and are enriched in Rb and Sr, and depleted in Y and Yb. However, the A-type magmatism is alkaline to peralkaline, formed in reduced conditions under low water fugacities (fO_2). They have high Fe/Mg, (Na + K)/Al, abundant Zr, Nb, Ga, Y, F and REE, and low Ca, Mg, Cr and Ni (Collins et al., 1982; Creaser et al., 1991). While the I-type granites, most likely originated by fractionation crystallization of a mantle-derived low-K basaltic magma (Singer et al., 1992; Barth et al., 1995) with crustal contamination (e.g., Hussein et al., 1982; Boztuğ, 1998; İlbeyli et al., 2004) or by anatexis of granulitic lower crust in subduction zones (e.g., Furnes et al., 1996; Moghazi, 1999), the A-type alkaline granites range from partial melting of the lower crust to extreme differentiation of mantle-derived tholeiitic or alkaline basaltic magma (Bonin and Giret, 1990; Turner et al., 1992; Collins et al., 1982; Frost and Frost, 1997; Patiño Douce, 1997; Muskhin et al., 2003; Huang et al., 2011). Assimilation of older crustal material into mantle derived granitic magma is a plausible model to account for the petrogenesis of such rocks (Eby, 1990, 1992; Kemp et al., 2006; Zhang et al., 2012).

In order to understand the tectonic setting of the Arabian Shield magmatism and to clarify the possible magma sources of the I-type granitoids and A-type granites, we report new geochemical and U-Pb zircon geochronological results for some granitic rocks from Jabal Ghadarah area along the Nabitah suture in the central Saudi Arabia.